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BASICS OF POLLUTION CONTROL: SEMINAR FOR UPGRADING DAIRY PRODUCTION AND TREATMENT FACILITIES TO CONTROL POLLUTION, MADISON, WISCONSIN, MARCH 20-21, 1973

Gurham and Associates, Incorporated
Chicago, Illinois

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The proceedings of this seminar outline the technical measurements, used by pollution control technologists, as they apply to the dairy industry. Technical terms used in the laws which control wastewater discharge are defined in industry terms. Waste quantities are expressed in standard parameters used in waste control regulation. Significance, sources, loadings, and limitations for each parameter and methods of analysis are discussed. Finally, a plant wastewater survey and evaluation of data collected are described. The appendix is a paper which explains devices and techniques used for measuring flows and sampling wastewater streams.

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Prepared

For

ENVIRONMENTAL PROTECTION AGENCY

TECHNOLOGY TRANSFER PROGRAM

SEMINAR

For

UPGRADING DAIRY PRODUCTION

AND TREATMENT FACILITIES TO

CONTROL POLLUTION

Madison, Wisconsin

March 20-21, 1973

GURNHAM AND ASSOCIATES, INC.

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Introduction

The purpose of this book on "Basics of Pollution Control" is to outline the technical measurements used by pollution control technologists, as these apply to the dairy industry. The Federal, State, and local laws which control wastewater discharges from the dairy industry, and the effluent standards and regulations that result from these laws, are written in technical terms. Correct interpretation requires a clear understanding of the technical words used. Without such an understanding, it would be meaningless to conduct a plant survey or to attempt to design treatment facilities that will assure compliance.

In an early section of this book, waterborne wastes are defined in industry terms; i.e., as spilled milk, cheese whey, cleaning solutions, and the like. Next, these waste quantities are expressed in the standard parameters of pollution control technology, such as are used in waste control regulations. The units in which these parameters are expressed are described, with a listing of the significance, sources, loadings, and limitations for each parameter. Methods of analysis are described briefly.

A later section of this book describes a program for the conduct of a plant wastewater survey, for the purposes of determining specific sources of pollution within the plant and measuring the quantities of each. This section includes evaluation of data developed by the survey. The appendix is a paper that explains the devices and techniques used for measuring flows and for sampling wastewater streams.

Sources of Waterborne Wastes from the Dairy Industry.

Process wastes.

- Whole milk (spillage, washups, etc.)
- Buttermilk.
- Whey.
- Skim milk.
- Centrifuge sludges.
- Entrainment losses.
- Condensates.
- Casein
- Curd
- Milk solids
- Butterfats

Ancillary wastes.

- Clean-ups
- Cleaning agents, disinfectants, and other chemicals
- Lubricants.
- Water treatment.
- Boiler blowdown
- Cooling waters.

Other wastes.

- Sanitary sewage.
- Kitchen and cafeteria.
- Laundry.
- Storm water.

Major Pollutants from the Dairy Industry.

Most significant parameters.

- Total suspended matter.
- Biochemical oxygen demand.
- Chemical oxygen demand.
- pH value.

Other significant parameters.

- Temperature.
- Odor.
- Color.
- Turbidity.
- Grease.
- Acidity and alkalinity.
- Dissolved matter.
- Total residue on evaporation.
- Total organic carbon.
- Ammonia nitrogen.
- Total Kjeldahl nitrogen.
- Phosphorus.
- Chloride.
- Total coliforms.
- Fecal coliforms.

Units of Measurement.

Concentration Units.

1. Milligrams per liter, mg/l or mg/liter.

Is the common concentration unit since about 1960.

1000 milligrams = 1 gram;

453.6 grams = 1 pound;

3.785 liters = 1 gallon.

Specific gravity should be noted if it differs significantly from 1.0; e.g., sludges and oils.

2. Micrograms per liter, µg/l or µg/liter.

Used for very low concentrations, e.g., below 0.1 mg/liter.

1 mg/liter = 1000 µg/liter.

3. Parts per million, ppm.

Was the common concentration unit until about 1960.

For most practical purposes, is identical with mg/liter.

1 liter of water weighs approximately 1,000,000 mg.

4. Parts per billion, ppb.

1 billion = $(10)^9$ = 1,000,000,000.

1 ppm = 1000 ppb.

5. Per cent, %

Used only for high concentrations, such as sludges.

e.g., above 10,000 ppm.

1% = 10,000 ppm.

Specific gravity is apt to differ significantly from 1.0.

Units of Measurement.

Loading Units.

Loading units are based on magnitude of flow, as well as on concentration.

1. Pounds per day

   Gallons/day x 8.34 x specific gravity = Pounds (flow) per day.

   Pounds (flow) per day x concentration in mg/liter ÷ 1,000,000 = Pounds of pollutant per day.

2. Pounds per unit of production.

   Unit of production may be 1 or 1000 pounds of milk processed, or other convenient unit.

   Pounds of pollutant per day ÷ units of production per day = pounds of pollutant per unit of production.

3. Other units.

   Variations of the above common loading units are possible; e.g., by use of metric units, other production units, or other time units.

Units of Measurement.

Miscellaneous and Special Units.

1. Population equivalents.

   Pounds of pollutant per day ÷ pounds of same pollutant equal to one person's daily discharge to municipal sewers = Population equivalent.

   Commonly applied to BOD, but can be applied to other parameters such as suspended solids or chlorine demand.

   For BOD, the daily per capita loading is 0.17 pound. (Note that the conventional daily per capita discharge of 100 gallons of sewage, at a BOD strength of 200 mg/liter, is equal to 0.17 pound BOD).

2. pH value.

   A measure of the ionic concentration of hydrogen ion, and thus of the strength of acid or alkali.

   pH is the base-10 logarithm of the reciprocal of the hydrogen-ion concentration in gram-mols per liter.

   pH is generally considered to range from 0 to 14, 7 being neutral, lower values acidic, higher values alkaline.

   Methyl orange endpoint = pH 4.5;

   Phenolphthalein endpoint = pH 8.3.

3. Special units are used for certain parameters, including temperatures, color, turbidity, odor, settleable matter, specific conductance, and coliforms.

Parameters of Pollution.

Total Suspended Matter.

Also called: Nonfiltrable Residue, or Suspended Solids (SS).

Includes: Materials removed by laboratory filtration. However, should not include coarse or floating matter, because of the impossibility of obtaining a proper sample.

Significance: A measure of visible pollution. Also a measure of material that may settle in quiet parts of natural streams or sewers, causing clogging, unsightly deposits or sludge banks, and similar problems.

Sources: Almost all processing areas in plant; also clean-up operations.

Raw Waste Loading: No "typical" value. A recent study of 18 dairies showed a range from 6 to 4,500 mg/l in wastewaters; average 710. At 2.4 pounds of wastewater per pound of milk received, this average corresponds to a discharge of 1.7 pounds of suspended solids per 1000 pounds of milk received. Approximately 75% of this is volatile (or organic) solids.

Limitations: Both waterway and sewer standards usually ban sludges and floating debris. Otherwise, some areas have no regulation, or the limitation may be as low as 35 mg/l for waterways, 200 for sewers. Surcharge ordinances often charge only for excess above 200 mg/l.

Analysis: Filter on glass fiber disc; wash; dry at 103^{o}C weigh.

Parameters of Pollution.

Biochemical Oxygen Demand (BOD).

Significance: An indirect measure of the biodegradable organic pollutant. More specifically, a measure of the oxygen consumed by aerobic decomposition of the waste, under carefully specified conditions. It can be related to depletion of oxygen in a natural stream, or to the oxygen requirements for waste treatment by aerobic biological processing (secondary treatment).

Sources: All organic materials that enter the waste stream, including milk solids, proteins, sugars, fats, and waste products.

Raw Waste Loading: Widely variable. A recent study of 56 dairies showed a range from 0.02 to 71 pounds per 1000 pounds of milk received; average 5.5 . At 2.4 pounds of wastewater per pound of milk received, this average corresponds to a concentration of 2300 mg/l.

Limitations: In streams, the BOD concentration should not be high enough to reduce the dissolved oxygen (DO) level too far; e.g., not below about 4 mg/l DO for most fish life. This is not a simple relationship, as the BOD reaction is slow, and DO is simultaneously replenished by natural means. Many states restrict the BOD of effluents to 20 or 30 mg/l; or to lower values if the stream flow is small in comparison with the flow of effluent. For discharge to a municipal sewer, a limitation of 200 or 300 mg/l is often applied; surcharge rates sometimes apply only above 200.

Parameters of Pollution.

Biochemical Oxygen Demand (BOD). (Continued)

Analysis: Incubate a sample at 20°C for 5 days, after mixing with oxygen-saturated water, biological seed, and chemical nutrients. Measure DO before and after incubation, and calculate the loss of DO as the BOD. All conditions must be carefully controlled, and procedures followed exactly (see analytical texts).

Parameters of Pollution.

Chemical Oxygen Demand (COD).

Significance: An indirect measure of total organic pollution. More rapid than the 5-day BOD test (page 8), but not the same in significance. Measures the amount of material oxidized by dichromate-sulfuric acid reagent, under carefully specified conditions. Includes some inorganic substances; not identical with the BOD test in what it includes and what it fails to include.

Sources: See BOD (page 8).

Limitations: Not commonly used as a regulatory parameter. Has been used in plant studies to compare organic wastes (BOD test is often too slow); frequently an approximate BOD: COD ratio can be determined.

Analysis: Treat sample with a standard amount of oxidant; hold at boiling temperature for 2 hours; measure amount of remaining oxidant; report amount consumed as oxygen equivalent.

Parameters of Pollution.

pH Value.

See also discussion on page 6.

Significance: Either high or low values may cause corrosion of metals, concrete, and other materials. Either is harmful to aquatic life.

Sources: Almost entirely from cleaning operations. Soaps and detergents are generally of high pH; strong acids (low pH) are sometimes used for scale removal and other difficult cleaning jobs. The development of septic conditions in milk wastes may also cause a low pH.

Limitations: Discharges usually restricted within the 5.5 to 10 range; frequently to only a portion of this range, such as 6 to 8.5 .

Analysis: By colorimetry (indicator solutions or test papers). More accurately, by electrometric instrument.

Parameters of Pollution.

Grease.

Also called: Oil and Grease; Hexane-solubles; Petroleum-ether-solubles.

Significance: Oily materials form unsightly films, interfere with aquatic life, clog sewers, disturb biological process in sewage treatment plants, and may be a fire hazard.

Sources: Almost all milk products contain fats.

Raw Waste Loading: Widely variable. A literature study based on 7 dairy plants reported wastewater grease concentrations from 35 to 500 mg/liter; average 210 .

Limitations: In waterways, grease is limited in that it must not be visible; a further proposed limitation is 10 mg/1. In sewers, a typical limit is 100 mg/1; some cities are more severe.

Analysis: Acidify; filter; dry; extract with hexane or equivalent; evaporate solvent; dry; weigh. Directions must be followed exactly (see analytical texts).

Parameters of Pollution.

Ammonia Nitrogen.

Nitrogen may exist in wastewaters in any of several forms, starting (usually) with protein (organic nitrogen), through various products of decomposition to ammonia, then by oxidation to nitrite and nitrate. A chemically intermediate form, elemental nitrogen, is inert and harmless.

Significance: In low concentrations, is a necessary nutrient for aquatic plant life; but too much may encourage eutrophication. Free ammonia is harmful to fish, and is corrosive to copper and copper alloys. Ammonia consumes oxygen during biological oxidation, and has caused fish kills by depleting dissolved oxygen.

Sources: Present in and develops from milk proteins. Also in ammonia leaks from refrigeration systems.

Limitations: Limited to 0.05 or 0.1 mg/l in drinking water. A rather severe effluent limit is 5 mg/l.

Analysis: Add alkali; steam-distill into a standard acid solution; titrate to determine acid neutralized. Report as N.

Parameters of Pollution.

Total Kjeldahl Nitrogen (TKN).

Significance: A measure of the ammonia and organic nitrogen. Used in conjunction with the ammonia nitrogen test to determine (by difference) the organic nitrogen. In waterways and sewers, decomposes to form ammonia nitrogen (see page 13).

Sources: See Ammonia nitrogen (page 13).

Limitations: Not a common parameter for regulation.

Analysis: Digest with nitric and sulfuric acid to destroy organic matter and convert to ammonia nitrogen; then determine as on page 13.

Parameters of Pollution.

Phosphorus.

Commonly reported as P; sometimes as PO_4 (phosphate). 1 part P = approximately 3 parts PO_4.

Significance: A necessary nutrient for aquatic plant life; hence sometimes a cause of eutrophication when present in excess.

Sources: Primarily from detergents; also present in milk proteins.

Limitations: Recent regulations are limiting discharge to streams to 1 mg/l as P.

Analysis: Determine colorimetrically by special reagents. It is sometimes desirable to distinguish dissolved and suspended phosphorus.

Parameters of Pollution.

Temperature.

Significance: In streams, high temperature (thermal pollution) decreases the solubility of oxygen, is detrimental to aquatic life, and accelerates the development of septicity. In sewers, it accelerates corrosion and septicity, and interferes with settling at the treatment plant.

Sources: Primarily from condensates and hot cleaning solutions.

Limitations: Stream temperature rise usually limited to a few degrees above ambient, with a maximum of 85 to 95°F. Sewer limitation is commonly 140 to 150°F.

Parameters of Pollution.

Odor.

Some analogy to taste, in significance, sources, and methods of determination. However, taste is not commonly measured or estimated in wastewaters.

Significance: Esthetically objectionable. May indicate other types of pollution, often resulting from septicity (anaerobic conditions).

Sources: Many sources; most important is spoiled milk and milk products.

Limitations: Usually restricted, but by qualitative indication only.

Analysis: Prepare sample in a series of dilutions, and determine "threshold" or barely detectable value. A panel of several experienced judges should be used.

Parameters of Pollution.

Color.

Significance: Primarily esthetics. May be troublesome for certain industrial uses, as in the food, paper, and textile industries.

Limitations: Drinking water limited to 15 color units; food processing water limits range from 5 to 20 units.

Analysis: Compare, visually or photoelectrically, with standards made from chloroplatinic acid compounds.

Parameters of Pollution.

Turbidity.

Significance: Esthetics. Also, by interfering with light penetration in streams, affects aquatic life and retards oxygen regeneration by photosynthesis. Detrimental to some industrial water uses.

Sources: Any source of finely suspended or colloidal matter, either solid or liquid. From practically every operation in the plant, including clean-up.

Limitations: Usually 10 to 50 units (JTU, or Jackson turbidity units) for domestic water supplies; 10 to 100 units for critical industrial uses.

Analysis: Measure, visually or photoelectrically, the transmission of light through a sample. May be by use of standards, or by threshold visibility, or by direct optical measurement.

Parameters of Pollution.

Acidity and Alkalinity.

A measure of the total quantity of acid (or alkali) present, measured below (or above) the neutral point of pH 7 or some other arbitrary point. Note that pH is a measure of the strength; acidity and alkalinity are measures of total quanity. Thus a small amount of strong acid (e.g., sulfuric) may produce a very low pH, while a large concentration of weak acid (e.g., acetic) may not produce a pH below 3 or 4; however, the latter would require a larger amount of alkaline neutralizing agent to restore a neutral condition.

Significance: Not as significant as pH as a measure of pollutional effects; but indicates quantity of chemicals required for treatment.

Sources: Same as for pH (page 11).

Limitations: None; but see pH limitations (page 11).

Analysis: Measure the quantity of a standard alkali (or acid) required to bring the pH to the desired point. This point may be neutrality (pH 7) or the endpoint of one of the common colorimetric indicators: methyl orange, 4.5, or phenolphthalein, 8.3 . The specific acid or alkali is not significant; values are reported in terms of calcium carbonate ($CaCO_3$) equivalent.

Parameters of Pollution.

Settleable Matter.

Also called Settleable Solids.

Significance: The settleable portion of total suspended matter. (see page 7).

Sources: See page 7.

Limitations: Limitations are usually based on total suspended matter. When limits on settleable matter are stated, they may be very low, e.g., 0.1 milliliter/liter.

Analysis: Allow the sample to remain undisturbed in a glass Imhoff cone, for one hour or other suitable period; record the volume of sediment accumulated, in milliliters per liter. Alternately, measure the total suspended solids in a sample both before and after settling, and report the difference in mg/liter.

Parameters of Pollution.

Dissolved Matter.

Also called Filtrable Residue, Dissolved Solids, or Total Dissolved Solids (TDS).

Significance: Very little, except in high concentrations of the order of 5000 mg/l (0.5 per cent). Harmful to humans and other animal life at high strength. Troublesome for certain industrial uses.

Sources: Milk sugars and soluble solids; cleaning chemicals; boiler blow-down.

Limitations: In drinking water, 500 mg/l.

Analysis: Calculate as the difference between Total residue on evaporation (page 23) and Total suspended matter (page 7). Alternately, filter (as on page 7), evaporate the filtrate to dryness, weigh.

Parameters of Pollution.

Total Residue on Evaporation.

Also called Total Solids (TS).

Significance: None, of itself; but see Total suspended matter (page 7) and Dissolved matter (page 22).

Sources: See pages 7 and 22.

Limitations: See pages 7 and 22.

Analysis: Evaporate to dryness; weigh. Alternately, add Total suspended matter and Dissolved matter.

Parameters of Pollution.

Total Organic Carbon (TOC).

Significance: Similar to COD (page 10). The organic matter (as carbon) is oxidized and the resulting carbon dioxide is measured. Corrections are possible for inorganic carbon sources (carbonates and bicarbonates).

Sources: See BOD (page 8).

Limitations: See COD (page 10).

Analysis: Proprietary equipment.

Parameters of Pollution.

Chloride.

Significance: Is a necessary element in biological life processes; but chlorides (principally salt) can be injurious at high concentrations.

Limitations: Usually none directly; but chlorides are part of the total dissolved solids, which are sometimes limited to 500 mg/l.

Analysis: Determine colorimetrically with special reagents.

Parameters of Pollution.

Coliform counts.

Significance: Total coliform count and fecal coliform count are used as indicators of pollution. It is not feasible to determine pathogenic organisms directly.

Sources: Sanitary wastes, which may enter the process wastewater stream.

Limitations: Variable among different areas. A "typical" limitation is 10,000 total coliforms or 2000 fecal coliforms, per 100 milliliters. Limits 1/100 of these have been cited as "desirable."

Analysis: Incubate in special plates or culture media. Sometimes expressed as MPN (most probable number); sometimes by direct count. Common unit is number per 100 ml.

Conducting a Plant Survey.

Purposes of the Survey.

To determine compliance with regulations.

- Or lack of compliance.
- Local.
- State.
- Federal.

To prevent public embarrassment.

- Or, if too late, to counteract it.
- Prevent nuisance suits.

To provide data.

- For a water management program.
- For detection of material wastage and losses.
- For water conservation and recycling.
- For design of a treatment system.
- For a discharge permit application.
  - Local, State, Federal.
- For calculation of surcharge rate.
- For use in private lawsuits by neighbors.

Conducting a Plant Survey.

Responsibility for the Survey.

Corporate management.

Company or plant management.

Plant technical staff.

    Engineering department.

    Plant engineer.

Plant laboratory.

Consultant.

    Should be familiar with:

        Waste treatment processes and design.

        Regulatory limits and procedures.

        The dairy industry and its operations.

Conducting a Plant Survey.

Planning the Survey.

Define and understand the purposes and goals.

Study the regulations that must be met.

List the data expected from the survey.

Obtain and verify maps and plans.

- Surrounding area.
- Plant area.
  - Building and department boundaries.
  - All waste sources.
  - Detailed sewer maps.

Obtain basic information on plant operations.

- Shifts and hours.
- Clean-up schedules.
- Production data.
- Water sources and usage.

Plan flow measurement and sampling program.

- Points to be studied.
- Flow measurement methods.
- Sampling and analysis program.

Train the survey crew.

Conducting a Plant Survey.

Measurement of Flows.

Locations:

- Water intake to plant.
- Water effluent from plant.
- Intermediate flows.
  - Individual process streams.

Methods:

- Direct meter.
- Bucket and stopwatch.
  - Sump or vessel filling.
- Weir.
  - Sharp-crested rectangular, right-angled V-notch, and other.
- Parshall flume.
- Cross-section/velocity measurements.
- Dilution method.

Other considerations:

- Temporary vs. permanent installation.
- Indicating vs. recording meters.
  - Integrating meters.
  - Signal to automatic sampler.

Conducting a Plant Survey.

Direct Monitoring.

Locations.

Plant effluent.

Possibly other locations.

Permanence.

Fixed vs. movable.

Parameters.

Temperature.

pH.

Turbidity.

Color.

Dissolved oxygen.

Conductance.

Conducting a Plant Survey.

Sampling.

See appendix: "Application of Automatic Sampling to Today's Water Quality Control Programs."

Selection of sampling sites.

Selection of sampling period.

Usually 24 hours; other periods may be better.

Frequency of sampling.

Type of sample.

Grab vs. composite.

At least, a representative composite for each 24-hour period.

Automatic samplers.

Sample preservation.

Sampling difficulties.

Stratified waste streams.

Coarse solids.

Cleaning and maintenance.

Conducting a Plant Survey.

Analysis.

Field vs. laboratory tests.

References:

Standard Methods for the Examination of Water and Wastewater. 13th ed., 1970. American Public Health Association, New York.

FWPCA Methods for Chemical Analysis of Water and Wastes. 1969. U. S. Department of the Interior.

197? Book of ASTM Standards, With Related Material; Part 23, Water, Atmospheric Analysis. American Society for Testing and Materials, Philadelphia.

Treatability studies.

Settleability.

pH titration curve.

Toxicity (bio-assay).

Biodegradability.

Conducting a Plant Survey.

Evaluation of the Survey.

First survey day is usually only a trial run.

Look for inconsistencies, inadequate data, etc.

E.g., individual waste total vs. effluent flow and analysis.

Some error is inevitable.

Preparation of material balances.

On water.

On individual pollutants.

Calculation of loadings.

Per day.

Per unit of production.

Variability during the day.

Comparison with other plants in the industry.

Recommendations.

Based on original (or modified) purpose.

APPLICATION OF AUTOMATIC SAMPLING

TO

TODAY'S WATER QUALITY CONTROL PROGRAMS

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Ontario Water Resources Commission
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A water quality control program is an organized and well thought-out plan for determining and controlling the quality of the water leaving a plant or of the water recirculating through plant processes. Metering, sampling, and analysis are essential keys to organizing the most economical and efficient program. Only through such studies can we gain the knowledge of water and wastewater characteristics which is essential to both the design and the operation of any water quality control program.

Every industry, from the small, isolated cheese factory to the multi-faceted industrial giant, should be aware of the increasing emphasis being placed on water quality control. Local, state, and federal agencies, pressured by an aroused citizenry, are rigidly enforcing existing laws and pushing for the passage of even more strin-

gent regulations. The industrialist can no longer afford to laugh off or ignore citizens' campaigns to "save the environment." If he fails to comply with water quality standards of his area, the fines imposed are outright business losses. A disregard for the wishes of the community in which he operates could ultimately lead to a shut-down or complete business collapse.

The industrialist is in business to make a profit. A sound water quality control program, one based on a real knowledge of the streams involved, can enhance the profit picture by reducing water usage and lessening the quantities of valuable materials lost as waste. Improved product yields, increased efficiencies of operation, and more equitable sewer use charges are additional benefits.

The initial step in developing a sound water quality control program is the metering, sampling, and analysis of all the significant streams leading into a plant, circulating through the plant, and leaving the plant. This procedure is basic to any of the following purposes:

1. To meet regulatory agency effluent requirements.
2. To determine equitable charges for joint treatment.
3. To design adequate treatment processes.
4. To plan for water reuse and conservation.
5. To determine product losses, either for the purpose of planning a recovery system or for the design of processes which prevent such losses.
6. To determine treatment efficiency and to trouble-shoot any process failures.
7. To design treatment plant expansion.
8. To serve as the basis for development of an automated treatment system.

There are several basic requirements for an effective program. Not only the program director, but each individual staff member - especially the plant operator - must know what the program is all about, why it has been initiated, how it will be conducted, and what it is expected to reveal.

Only the very largest of industries find it economical to employ specialists in water pollution abatement. For most plants, it is more efficient to retain a qualified pollution control consultant as director of the water quality control program. He has had experience in similar projects; he is familiar with the latest equipment, technology, and regulatory agency requirements; and he is qualified to interpret the data and to make process changes or design recommendations.

A second basic requirement for a successful program is a sound knowledge of sampling procedures and equipment. The accessibility of sampling sites, the general character of wastes and their flow pattern, and the analysis to be made are all variables that must be considered.

Requisites for a Sampling Program

To fulfill any or all of the purposes of a program, samples must be truly representative. The composition of the sample must be in close agreement with the composition of the stream from which it was taken and which it is assumed to represent.

Careful selection of the sampling site is crucial. Typical streams to be sampled include influent, effluent, laterals, receiving water above and below the outfall, effluents from each of the specific processes, pretreated or partially treated waste streams, and storm drains. Ideally, each sampling point should include all pertinent substreams and should exclude other streams that might contribute dilution or interfere with the analyses to be made. Pertinent substreams should be well mixed. Each stream to be sampled should have some form of flow measurement device. The site should be safe and reasonably accessible.

Unfortunately, many areas to be sampled are far from ideal, particularly in older industrial plants. When the preferred sampling site is located under a several-foot layer of concrete, or when an outfall is below the water level of the receiving stream, compromises must be made. Sometimes it is necessary to sample several contributory streams which made up the flow at the inaccessible site, and to combine these samples in proportion to their flow contribution. This procedure can result in a reasonable approximation of the actual effluent.

Selecting the time period for sampling is also crucial. A 24-hour composite is generally considered to be the most practical and convenient sample period. However, longer or shorter periods of time may be dictated by operating schedules, weekends, or potential process upsets. If the water quality program is to include goals of product loss control, by-product recovery, and water conservation, it is particularly helpful to have data from each shift of operation. Hour by hour sequential composites can also pinpoint processes or operations which are causing particular problems or losses. In addition, there are often psychological benefits to be derived from such procedures. Supervisors and shift personnel usually react positively to the knowledge that they will share credit for water quality improvements originating on their shift.

Areas where flow is intermittent require special attention. These areas, which include storm drains and wash-down sites, frequently contribute significant volume and pollutant to the sewer system or receiving waters. Yet flow exists during only a small portion of the sampling period. Other streams need be sampled only when certain conditions exist, such as flow greater than a specified minimum, high or low pH, high temperature, or a specific ion. Equipment can be selected which will sample only when predetermined parameters exist.

Selecting the time base for sampling is the next important step in developing a program which will yield representative samples. The simplest method is to collect samples on a regular time basis. This is

the most practical method - sometimes the only method, for sampling streams of fairly regular flow, large receiving waters, or areas where flow measurement is not possible. The frequent collection of a regular quantity of sample on a regular time schedule may be expressed "VcTc" - volume of sample constant, time interval also constant.

Types of Sample

There are six major types of samples, labeled by their base and method of collection: individual or "grab", simple composite, sequential composite, continuous, hand proportioned composite, and automatic proportioned composite.

1. The individual or "grab" sample is retained as a separate entity in its own container. In the extreme case, for very small flows, the entire stream can be collected during the time interval selected, then mixed, and an aliquot taken.

2. The simple composite requires that all of the samples taken over the specified time interval be deposited in a single container. If, however, the composite is to be analyzed for oily materials by the API method, it must be split into two separate containers. This is true also if two different methods of preservation are required (other than refrigeration) for the proposed analyses.

3. The sequential composite requires the collection of a series (usually 2 to 8) of individual samples per container, each container representing a specific time period. Such a procedure is particularly useful where the character of the waste may vary significantly from hour to hour, where batch dumping is expected, or where self-cancelling conditions occur, such as alternating high and low pH, which would not be apparent in a simple composite sample.

4. Continuous sampling, in which a very small amount of sample is collected in continuous flow, is useful for feeding monitors or pilot scale processes, or for sampling receiving waters. This technique is not recommended where the stream is high in suspended solids. If the continuous sample is composited, the product is large, at times too large to be conveniently handled.

5. The hand proportioned composite can be obtained where flow charts are available. Individual or sequential composite samples are manually composited in accordance with the flow to obtain this useful and representative type of sample.

6. The automatically proportioned composite does require additional equipment and an understanding of the principles of proportioning, but is not especially complicated. Sampling in proportion to flow may be accomplished in either of two ways: by varying the frequency of sampling in inverse ratio to flow, or by varying the size of individual aliquots in proportion to flow volumes.

Where there is a transmitting flowmeter available, or where the flow follows a sufficiently regular pattern that it can be translated to a characterized cam programmer, the automatic sampler can be designed to collect and composite fixed amounts of sample whenever "x" gallons of flow are measured. The time between samples is thus varied by the volume of the flow, resulting in more frequent samples when flow is high, fewer when flow is low. This may be expressed as "VcTv" - volume of sample constant, time between samples variable.

Where there are no flowmeters, but where flow is caused or varied by the operation of a pump, it is possible to correlate pump capacity and running time, to actuate the sampler after "Y" minutes of pump operation and hence after every "x" gallons of flow. This method provides a means of collecting a flow-proportioned composite without a flowmeter or primary element; it also, indirectly, produces a reasonably accurate measurement of flow. It has been used successfully in combined sewer overflow research projects and in industrial waste installations where tributary flows are collected in wet wells and pumped intermittently to the treatment facilities.

The second method for collecting flow-proportioned composites does not require an integrating flowmeter, but only a primary flow measuring element such as a weir or flume which creates a known head-to-flow relationship, and a scoop or ejector sampler characterized to the weir or flume. This method reverses the volume-time relationship by collecting a variable amount of sample at regular intervals. It may be expressed by "VvTc" - volume of sample variable, time between samples constant.

Although weirs are generally less expensive and easier to install, it is preferable to install a Parshall or Palmer Bowlus flume if the wastes tend to stratify or if they have significant amounts of settleable solids or floating oils. Flumes also create a minimum flow restriction and head loss in the channel being measured; whereas constrictions and head loss of a weir cause back-up and sometimes flooding; and the weir plate may collect settleable solids, which interfere with measurement and sampling.

Which of these two ways of collecting samples in proportion to flow, VcTv or VvTc, is the most accurate, and feasible? The answer depends on the hydraulics of the site to be sampled, the character of the wastes, convenience, safety, budget, and whether the installation is to be permanent or temporary.

Where flowmeters are already installed or planned, the most convenient method of proportioning is to use a sampler that is paced by the flowmeter to select constant volume samples at intervals varied by the measured flow. Automatic samplers that operate on this principle are available from less than $300.00 for a portable model to more than $2,000 for a unit that includes refrigerated sample storage and provides for installation in the laboratory or other convenient location some distance from the sampling site. This type of sampler produces representative composites as long as the unit is properly installed, the wastes are well mixed, and the flow does not vary more than about a 5 to 1 ratio.

In areas where there are no flowmeters, but where it is possible to install a weir or flume, it may be less costly to collect flow-proportioned samples with a proportional or characterized scoop. In situations where flows vary greatly, carry heavy waste concentrations at low flow, contain floating oils and solids, or tend to stratify, the only way to get a truly representative sample is to cross-section the stream depth on a regular time base with a characterized scoop. Another useful feature of the characterized scoop method of proportioning is that the total volume of the composite can be used to determine the total flow for the sampling period, without the use of a flowmeter.

Select Samplers Realistically

After the sites and the time base for sampling have been decided, the equipment can be selected. All of the variables mentioned above must be considered; accessibility of sampling site, general character of the wastes, flow patterns, and the analyses to be made.

A great many noncommercial or "home-made" sampling devices are currently in use, in industry and elsewhere. Many of these are extremely ingenious; a somewhat lesser number are adequate for their intended purpose; and some are fully satisfactory. Whether home-made or proprietory, equipment selection should be based on a realistic evaluation of cost, including engineering and labor, cost of operation, simplicity of operation, reliability, and maintenance. Equipment must be suitable for the conditions under which it will function. Therefore it is necessary to consider the following questions:

1. Will the installation be permanent or temporary: if temporary, should it be portable? Will the unit be indoors or outdoors, protected or exposed to weather conditions. How convenient is the access?
2. What are the power requirements: 110-volt AC, low voltage battery, compressed air, liquified gas, vacuum, or some combination of these?
3. Are the necessary flowmeters, weirs, or flumes available, or is their installation possible?
4. What is the lift required or head available?
5. Will the equipment be expected to function under hazardous conditions: in the presence of explosive or toxic materials, in corrosive or damp areas, under high or low temperatures?
6. Will the equipment be liable to damage by accident? Will it be accessible to vandals?

The proper equipment to do the job is not always the most expensive and elaborate device on the market. Each type of equipment must be judged according to its capabilities and limitations, as well as for its operational characteristics as applied to the particular stream to be sampled.

Why select automatic samplers? Because they are ready and willing to work 24 hours a day; hence automatic samplers reduce the man-hours necessary to carry out a program, and provide a more reliable product than hand sampling. The number of modifications commercially available

makes it possible to tailor a unit to the particular job. Automatic samplers are first classified as portable or permanent. Permanent samplers are further classified as to the method used for collecting samples, including: cup or bucket-elevator, scoop, vacuum or compressor, and pump.

The cup or bucket-elevator sampler must be placed directly over the pipe or channel carrying the waste. It can be adjusted to collect samples from depth within the flow. Floating materials in the stream, however, tend to collect on the chain or sprocket and subsequently foul the mechanism.

Either characterized or fixed volume scoop samplers are available. The characterized scoop, better known as the Trebler scoop, is shaped to collect a volume of sample that is proportional to the flow over a weir or through a flume. The head-to-flow relationship of the primary element determines the curve of the scoop required. Characterized scoops are available for use with V-notch weirs (30°, 60°, and 90°), rectangular weirs with or without end contractions, Cipoletti or trapezoidal weirs, Parshall flumes, and Palmer Bowlus flumes. When used with a weir, the characterized scoop rotates or oscillates into the stream to the depth of the datum line of the weir, to collect samples of the liquid which actually passes over the weir. When used with a Parshall or Palmer Bowlus flume, the scoop passes through the entire depth of the stream and collects a full cross-section of the flow from bottom to top.

The fixed volume or "M-S" scoop, developed by McGuire and Stormgaard, is shaped to collect a fixed volume of sample regardless of the depth of the stream. It can be used to collect flow-proportioned samples if it is paced by a flowmeter, a flow characterized cam programmer, or a pump running-time totalizer.

Scoop samplers are well suited for wastes that have a high grit content, that tend to stratify, or that have floating solids or oils. They must, however, be located directly over an open channel or in a manhole with a sufficient space for raising and lowering of the scoop. An oscillating scoop requires less space than a rotating scoop.

Vacuum or compressor samplers draw or eject samples from a vessel immersed in the waste stream. The shape of the vessel may be such that it fills in proportion to the flow through a primary element. Samples may be lifted from deep sewers or conveyed to areas safe from toxic gases. The units are inherently explosion-proof if the electrical components of the programming device are located away from the hazardous area. However, they require both electrical power and a source of compressed air or inert gas. The use of compressed air makes the samples unsuitable for disolved oxygen analysis, but nitrogen or other inert gas can be used to partially circumvent this problem.

There are numerous variations of the pump sampler. One model continuously pumps a portion of the stream to a remote chamber from which samples are dipped, scooped, or siphoned to a sample container. Another

model continuously pumps a portion of the wastestream to a location where a time or flow-activated valve momentarily diverts the entire pump throughput to a sample container. A third version intermittently pumps a portion of the stream, and a portion of this throughput is diverted to a sample container. A fourth variety is equipped with a low capacity or peristaltic pump which, operating either continuously or intermittently, transfers its entire throughput to a single container or series of containers.

The inlet on pump samplers must be located in a well-mixed position of the stream. Exhaust or unused throughput should be returned downstream of the inlet and flow measuring device. Pump capacity must be great enough that the liquid remains well mixed, particularly where there is horizontal piping in which solids could settle. With low capacity or self-priming pumps, lift should be kept to a minimum to insure representative pick-up of solids and to prevent settling in the inlet line. Inlet velocity must be at least 1/4 to 1/2 feet per second. Provision for flushing, backwashing, or draining to remove previous samples is essential in models which pump intermittently. Submerged or positive displacement pumps make it possible to locate the sampler in a safe, convenient area; they also overcome lift or other hydraulic problems at the site.

If wastes contain appreciable quantities of fibrous materials or have high grit content, pump impellers and shafts must be cleaned or replaced frequently. The type and capacity of the pump used in any model determines the sampler's ability to handle various types and quantities of particulate matter in the stream.

Several commercially available permanent samplers provide mechanically refrigerated storage areas for preservation of the collected samples. Others can be supplied with separate refrigerators modified to permit transfer of the sample directly into the container located inside the refrigerator.

Those samplers which pump through a weir chamber for collection by a dipper usually provide areas which can be used for probes to record constantly changing parameters such as pH, temperature, dissolved oxygen, and specific ions. Alarms can be connected to these probes to signal parameters outside of a predetermined range.

Portable samplers are designed for temporary installation and convenient relocation. They are particularly useful for survey work, regulatory agency investigations, and research studies. They are invaluable for trouble shooting treatment plants, checking effluent from various processes and substreams within an industrial plant, and determining the quality of the receiving waters above and below an outfall.

Portable samplers with pumps may be operated by line power (115v.AC), dry cells, or storage batteries. One portable pump sampler can be used in conjunction with a transmitting flowmeter to produce flow-proportioned composites. Several models collect a number of individual samples or

sequential composites. These are particularly useful where flow-proportioned samples are not possible, or where the quality of water or waste varies from hour to hour because of production or process operations. Other samplers are operated by canned gas (Freon), or by the vacuum produced by evacuation of the sample bottles in conjunction with a spring clock drive. Portable units which are operated by batteries, gas, evacuation, or spring-wound mechanisms have limited power and lift capacity, and must be frequently replaced, recharged, renewed, or rewound. Their chief value is that they make it possible to sample automatically in areas where there is no other source of power. The vacuum powered or suction sampler is inherently explosion-proof, and is the only sampler which can be used safely in an explosive atmosphere. Special provision can be made to start some portable samplers on command when storm flow or other specific conditions prevail.

Obviously the sampler must produce a sample of adequate size for the testing program planned. Preservation of the sample is often an important consideration. Preservation of samples by mechanical refrigeration is not usually a built-in provision of portable samplers, but samples can be kept chilled by enclosing the sample container with ice, dry ice, or cans of "Skotch Ice." In cold weather, protection from freezing may be equally significant. Chemical preservatives can be used if they do not interfere with the analysis to be done on the sample; sometimes chemical preservatives are required to protect certain "delicate" parameters from change.

Whether a permanent or a portable sampler is selected, it is important to give some thought to the container. This must provide an adequate volume of sample for the analyses which will be run, and must have sufficient capacity for unusually high flows when proportional samples are taken. The container material should not react with the contents of the waste, and must be easy to clean and convenient to handle.

To make the right equipment choice, it is necessary to compare and coordinate conditions at the sampling site with the capabilities of equipment available within the budget provided. Accuracy and reliability in collecting representative samples are essential if the cost of the analyses and data handling are to be justified. Manufacturer's literature provides much of the information needed. However, the services of a pollution control consultant are worth far more than their cost.

No matter what type of automatic sampler is selected, it will be the least expensive part of the over-all water quality control program. No investment, however small, is justifiable if the samples are not analyzed and if the data is not continually reviewed. Accurate, up-to-date records and regular reports to management are necessary. The correlation of production schedules and housekeeping procedures with waste volume and characteristics may reveal product losses, leaks, or excess water use.

Proper use of the data can result in reduced costs for utilities, chemicals, or sewer use. A reduction in hydraulic loading may allow for increased production without treatment plant expansion. Reductions in

BOD, COD, phosphates, solids, and metals cut treatment costs and prevent citations or law suits. Data may pinpoint troublesome wastes which can be isolated and treated more economically at the source.

An adequate understanding and knowledge of the waste stream can come only from metering, sampling, and analysis and from the coordinated water quality control program. This knowledge is an economic, technical, and legal necessity if industry is to continue profitable operations. None of this, however, is worthwhile if the samples are not representative of the streams from which they come.

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